Field evaluation of Australian wheat genotypes for competitive traits and weed suppression

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Summary In 2014 and 2015, replicated field trials were performed at commercial paddocks in moderate to low rainfall zones at Wagga Wagga and Condobolin NSW, respectively. In 2014, a total of 11 winter wheat cultivars (*Triticum aestivum* L.) representing four major breeding family lines grown in Australia were evaluated with 13 cultivars assessed in 2015. At each site, crop and/or weed growth were monitored at various stages of growth: early season (tillering), vegetative, grain filling, harvest and post-harvest. Significant differences between wheat cultivar and location were observed for crop biomass, early vigour, leaf area index (LAI), weed number, weed biomass, canopy architecture and yield in both 2014 and 2015. Differences in weed suppression were largely impacted by crop architecture and phenology early in the growing season. Cultivar competitive traits were also influenced by both genotype and environmental factors, as shown by clear differences in cultivar performance, yield and weed suppression among both locations. Cultivars Condo and Espada were superior performers for yield and weed suppression in both locations and years analysed. This data supports the concept that choice of wheat cultivar can prove to be a cost effective means of weed management.

Keywords Weed suppression, canopy architecture, phenology, propagules, weed seedbank.

INTRODUCTION

Herbicide resistance in both grasses and broadleaf weeds is on the rise across Australia, with an increasing number of cropping weeds experiencing resistance to multiple herbicides (Owen *et al.* 2013). Globally, weeds have evolved resistance to 22 of the 25 known herbicide modes of action and to 160 different herbicides (Heap 2016).

Highly competitive wheat cultivars typically have the ability to access better light, nutrients, and water resources in a limited space, thus suppressing the growth and reproduction of neighbouring weed species (Bertholdsson 2011, Worthington *et al.* 2015). In Greece, the use of competitive wheat cultivars alone has reduced the use of herbicides by 50% for weed management (Travlos 2012, Andrew *et al*. 2015). However, in the past century, the competitive ability of wheat has been typically reduced by selection based on yield potential. Older cultivars or landraces have been shown to be more competitive with weeds than the higher yielding, semi-dwarf modern cultivars (Bertholdsson *et al*. 2012).

To realise the potential of competitive crop cultivars as a tool in integrated weed management, a quick and simple-to-use protocol for assessing their competitive potential is required as it is likely that selection will not be based on a single trait, but will need to capture the combined effect of multiple traits (Bertholdsson 2011, Andrew *et al.* 2015). In this study, both field and laboratory experiments were performed with the overall objectives of 1) assessing the competitive traits of selected superior Australian winter wheat cultivars which are well adapted for the southern faming region, 2) assessing the impact of environmental factors associated with location and year, including soil moisture and temperature, on weed suppressive ability of wheat, 3) identifying and quantifying key wheat metabolites associated with weed suppression and 4) evaluating weed suppression by remaining wheat stubble post-harvest.

MATERIALS AND METHODS

In 2014 and 2015 field trials were sown at two locations in moderate to low rainfall zones at Wagga Wagga (572 mm) and Condobolin (449 mm) NSW, respectively. Plots were seeded with six replications in a randomized complete block design. Eleven wheat cultivars representing four major genetic families of winter wheat commercially grown in Australia were selected for evaluation, plus one cultivar of winter cereal rye (*Secale cereale*) as a known suppressive control. In 2015, two additional cultivars, Trojan and Federation, were included. Trojan is a recently released cultivar and Federation is an older heritage cultivar bred and released in 1901 and widely used until 1970. Soils were typical Aeolian fine red clays with clay content varying with soil depth.

At sowing, replicated soil samples were taken from each block to evaluate the weed seedbank in the glasshouse. At Condobolin, the crop was sown on 6th and 15th May at 33 cm spacing while at Wagga Wagga the crop was sown on 20th and 22nd May at 25 cm spacing for 2014 and 2015 respectively. A knife point and press wheel planter was used. Fertilizer was applied at 70 kg ha^{-1} MAP (Incitec Pivot Fertilisers). Equal plant density of each cultivar was established in each trial (target 120 plants m^{-2}) by assessment of seed weight per volume when seeding to reduce confounding effects for enhanced evaluation of cultivar competitiveness. No pre- or post- emergent herbicides were applied at either site during wheat production.

All data collection was performed at the critical plant developmental stages of stem elongation, flowering, maturity as well as post-harvest stubble residue assessment. Data collected each year included crop phenological characteristics, percentage light interception using light Ceptometer (AccuPAR LP-80 Ceptometer, Decagon Devices®) to measure PAR (Photosynthetically Active Radiation) both above and below the crop canopy, NDVI (Normalised Difference Vegetative Index) readings (GreenSeeker® 505 hand-held sensor and Trimble Recon PDA) to monitor crop biomass production, biomass cuts of crop and weeds (g m^{-2}), visual vigour ratings (0 = poor, 10 = excellent), yield (kg ha^{-1}) and post-harvest weed suppression(0 = poor, 10 = excellent).

Crop and weed biomass data were collected within a 50 × 50 cm quadrat in each plot at the soil surface with two subplots collected per plot. Grain harvest was performed before 15th December in each year and each location, using a small plot harvester. Yield was measured as harvested cereal grain. Statistical analysis of data was performed by ANOVA for randomised block experiments with six replicates using GenStat (VSN, 2016); significant differences were separated using LSD (0.05).

RESULTS AND DISCUSSION

At each location, cultivar differences were significant for crop growth parameters, including early vigour, leaf area index, NDVI, and crop biomass. Weed numbers and weed biomass were also significantly affected by crop cultivar at each location. Figure 1 depicts cultivar differences in early vigour and weed suppression at Wagga Wagga. Tables 1 and 2 reflect weed suppression provided by various wheat cultivars in terms of weed biomass taken at approximately 100 days after crop emergence (DAE) at both locations in 2014 and 2015.

Based on the results from 2014 and 2015 growing season, Condo, Janz Cl and Espada demonstrated enhanced crop competitive ability against weeds in contrast to other cultivars. At Wagga Wagga in 2015 (Figure 1 and Table 1), Federation, Condo and Janz Cl cultivars demonstrated strongest early vigour in terms of wheat growth at 57 days after establishment (DAE) and subsequently provided the greatest weed suppression at 110 DAE. Similar trends in weed suppression were also observed in 2014; Janz Cl, Espada and Condo were highly weed suppressive (Table 1).

Crop competitive ability can either be specified in terms of crop tolerance against weeds or growth inhibition of weeds by resource competition (Bertholdsson 2010). Previous studies have found that cultivars with higher early vigour are generally capable of extracting more soil moisture which in turn enables them to maintain lower canopy temperatures on warm days (Zerner *et al*. 2008) which is essential in dryland broadacre farming. Certain wheat cultivars under ideal conditions will produce acceptable yields while suppressing weed populations (Worthington *et al*. 2015, Andrew *et al*. 2015).

Condo and Espada were amongst the three most weed suppressive cultivars and also produced the highest grain yields (4.0 and 3.9 t ha^{-1} in 2014 and 5.4 and 5.6 t ha^{-1} in 2015 respectively; data not presented). Recent studies have also shown that certain cultivars successfully reduced the economic burden of weeds over time by resisting yield loss (Vandeleur and Gill 2004) while reducing weed seedbank inputs through successful suppression. Lemerle *et al*. (2001) also observed that cultivars which showed competitive yield advantage also suppressed *L. rigidum*.

At Condobolin in 2014, Mace was highly weed suppressive but was not significantly different from Espada, Condo and Janz Cl. Gregory was significantly less weed suppressive than other cultivars evaluated (Table 2). In 2015, Trojan, Condo, Scout and Espada were most weed suppressive. The ability to suppress weeds appears to be strongly cultivar dependant (Bertin *et al.* 2003, Wu *et al.* 2001). However, environmental factors such as moisture availability and daily temperature also play a key role in influencing the performance of specific genotypes in a particular season as shown by locational performance differences.

The competitive ability of wheat is influenced by a range of plant attributes such as height, tiller number, and light interception by the canopy or light interception at the soil surface. If one can limit light interception at the soil surface, the germination and establishment of weeds can often be significantly reduced. In recent experimentation, increasing plant height improved bread and durum wheat's ability to tolerate and suppress oats. Several plant traits associated with early wheat vigour (early canopy cover, greater leaf width and tiller number) were also

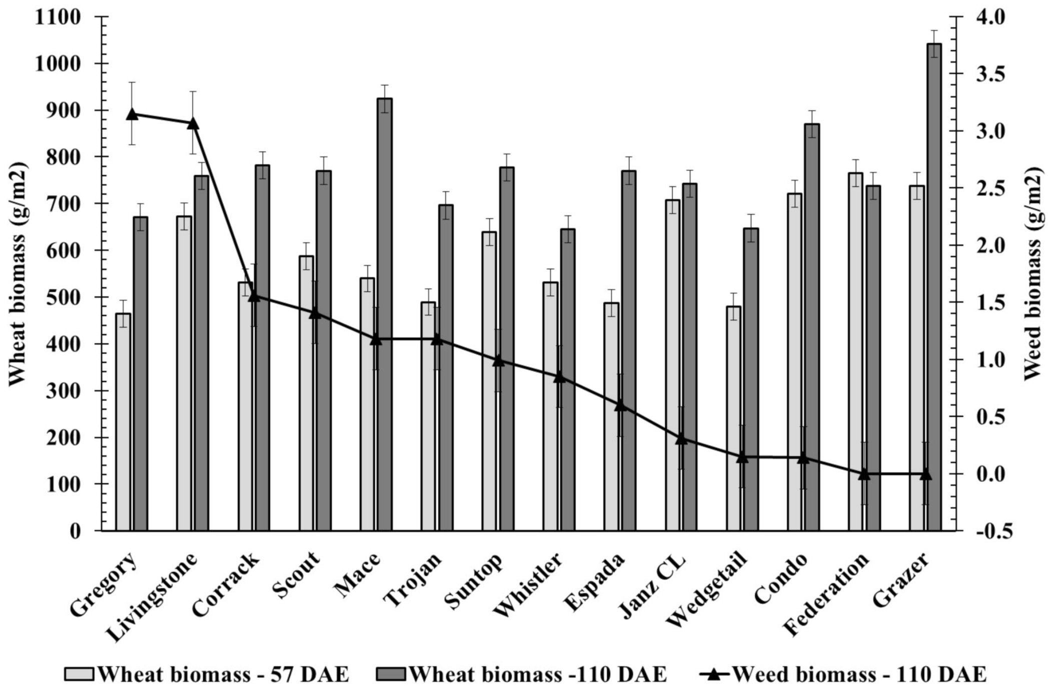

Figure 1. Wheat cultivar biomass taken 57 DAE (LSD 151; P <0.001) and 110 DAE (LSD 106; P <0.001) and weed biomass (LSD 2.9; P <0.5) taken at 110 DAE at Wagga Wagga in 2015 arranged by weed biomass from highest to lowest.

Table 1. Weed biomass (g m^{-2}) taken 130 and 110 DAE at Wagga Wagga in 2014 and 2015 respectively.

2014			2015		
Rank	Cultivar	g m^{-2}	Rank	Cultivar	g m^{-2}
1	Rye	1.1	1	Rye + Federation	0.0
2	Janz Cl	2.5	2	Condo	0.1
3	Espada	3.3	3	Janz Cl	0.3
4	Condo	5.1	4	Espada	0.6
5	Gregory	5.7	5	Trojan + Mace	1.2
6	Livingstone	7.3	6	Livingstone	3.1
7	Mace	13.5	7	Gregory	3.2
P – value		**NS**			*
LSD 0.05		**10.9**			**2.9**

Table 2. Weed biomass (g m^{-2}) taken 133 and 109 DAE at Condobolin in 2014 and 2015 respectively.

2014			2015		
Rank	Cultivar	g m^{-2}	Rank	Cultivar	g m^{-2}
1	Mace	0.03	1	Trojan	4.9
2	Espada	0.04	2	Condo	7.6
3	Condo	0.06	3	Livingstone	11.6
4	Janz	0.06	4	Espada	11.9
5	Livingstone	0.07	5	Federation	12.4
6	Rye	0.23	6	Janz	21.1
7	Gregory	0.70	7	Gregory	44.3
P – value		*			*
LSD 0.05		**0.5**			**30.5**

positively correlated with crop competitive ability (Vandeleur and Gill 2004, Zerner *et al*. 2008).

High leaf area index is known to be important in light interception (Figures 2 and 3). Federation, Condo and Grazer rye had the highest leaf area index of all crops and cultivars in Wagga Wagga, and this trait is most closely associated with early vigour growth and crop competitive ability (Vandeleur and Gill 2004, Zerner *et al*. 2008), but is not always selected for in current commercial lines and cultivars. Previous studies have also reported that early leaf area development is an important contributor to weed competitive ability (Coleman *et al*. 2001).

In Wagga Wagga in 2015 cultivar light interception was highly positively correlated to leaf area index at 57 days after crop emergence ($r^2 = 0.97$, $P < 0.001$; Figure 2). A similar relationship was also seen at Condobolin in 2015 (Figure 3) with cultivar light interception being highly positively correlated to leaf area index at 107 DAE ($r^2 = 0.89$, $P < 0.001$). However, after this time there was no significant correlation between these traits, suggesting crop height and other growth characteristics were important in light interception. For example, Federation and Condo cultivars in Wagga Wagga at 57 DAE were weed suppressive, having less than 50% of photosynthetically active radiation reach the soil surface compared to Wedgetail which had over 70% reach the soil surface. This suggests that the canopy of Federation and Condo successfully intercepted more light than did Wedgetail while allowing less to reach the soil surface, thereby influencing weed establishment (Table 1 and 2).

Plant height was also identified as one of the traits most commonly associated with competitiveness (Vandeleur and Gill 2004). However, timing of emergence also influences light interception, as the same weed species may be relatively tall or short depending on the emergence time relative to the crop. It is important to consider these cultivar competitive traits at breeding and sowing.

We have demonstrated that crop phenology early in the season may be particularly important in impacting overall weed suppression and the subsequent weed seedbank at the time of harvest. Initial studies over two years in two locations in the moderate to low rainfall zone show that the choice of wheat cultivar can prove to be a cost effective means of weed management and may potentially impact weed propagule numbers in the subsequent seedbank.

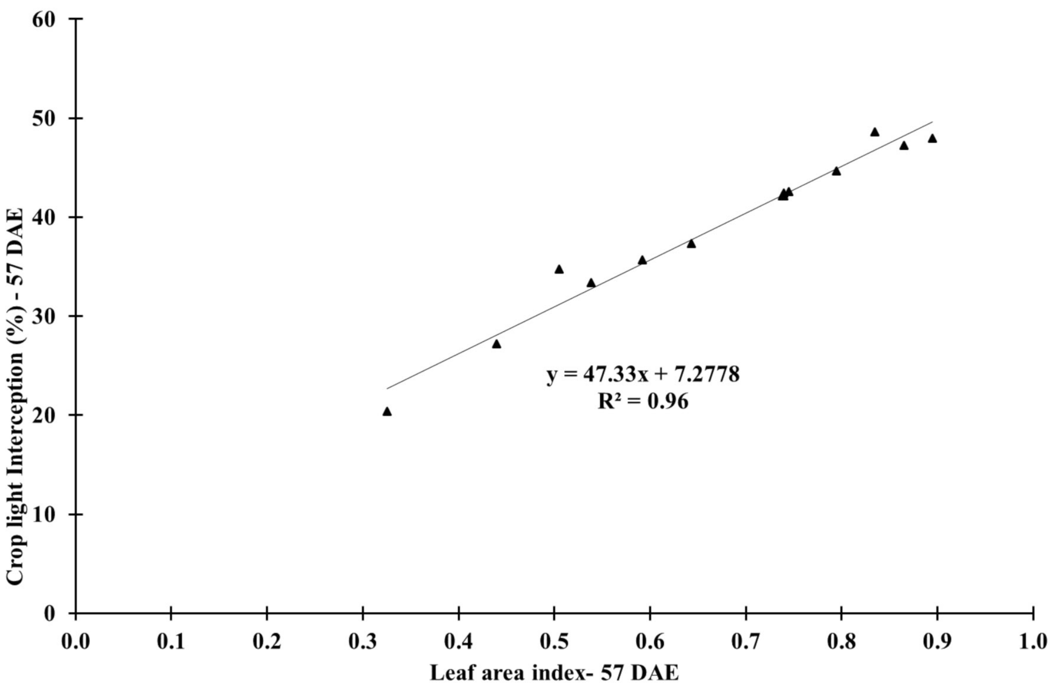

Figure 2. The relationship between wheat cultivar ground surface PAR light interception and leaf area index at 57 DAE in Wagga Wagga in 2015 ($r^2 = 0.97$; $P < 0.001$).

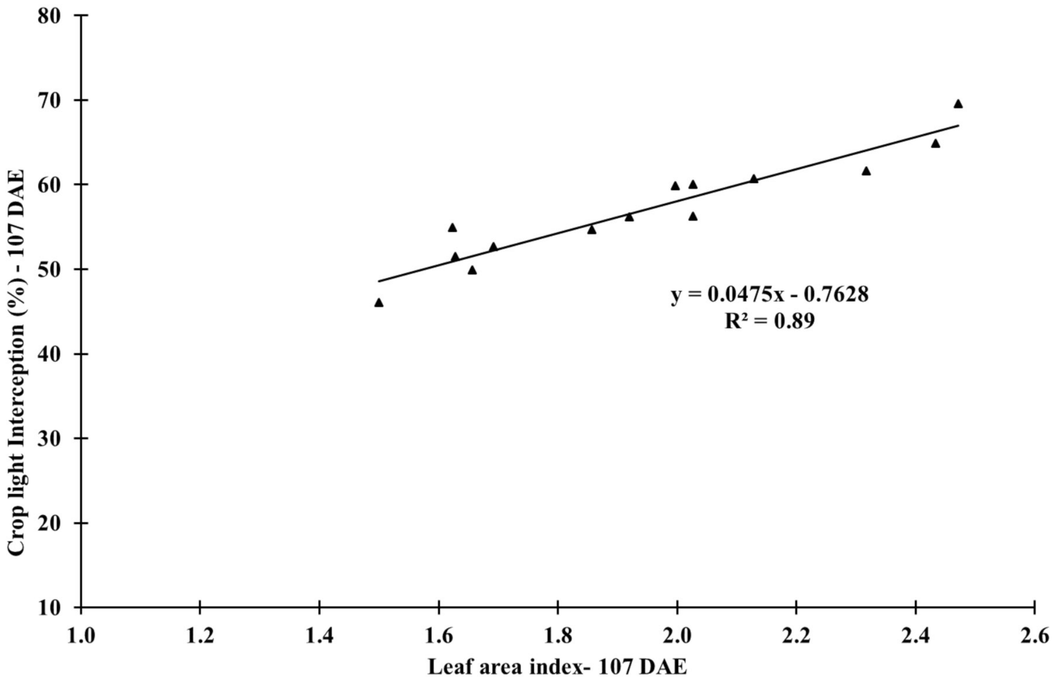

Figure 3. The relationship between wheat cultivar ground surface PAR light interception and leaf area index at 107 DAE in Condobolin in 2015 ($r^2 = 0.89$; $P < 0.001$).

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